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ABSTRACT

This study examines the impacts on pecan production that could result from adoption of a newly developed multi-pest management program for Southeastern pecans. The cost of the program is greater than the cost of conventional control of pecan pests. Analysis of yield data suggests, however, that employment of the multi-pest management program may increase pecan yield over that obtained using the conventional system of pesticide applications. The value of yield increases on experimental acreage was sufficiently high to offset the increassed cost of pest control. Further research is required to examine the impacts of widespread adoption of the program.

Key words: Budget analysis, Multi-pest management program, Pecan pest control.

* *
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* research community outside the U.S. Department of Agriculture. *
* The views expressed herein are not necessarily those of ESCS *
* or USDA. *
* *

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CONTENTS

HIGHLIGHTS

USDA's Byron, GA research station developed and tested a multi-pest management program for pecans. Results of the experiment were compared to conventional controls. Analysis of variance was conducted on the mean pecan yields obtained on two experimental plots, one of which was treated conventionally for pecan pests from 1975-77 and one on which the pest management program was employed during the same period. No significant yield differences were found to have occurred in 1975 or 1976. In 1977, the mean yields on the pest management orchard were significantly higher than those for the conventionally treated orchard. The costs of the pest management program were approximately 56 dollars per acre higher than those for conventional control. A production budget was developed for each pest control scenario based on experimental data. Budget analysis results indicated that, at 1977 prices and when all preharvest and harvest pecan production costs are considered, yield increases of approximately 102 pounds per acre of Stuart or 87 pounds per acre of Schley pecans would be required to equate an individual growers net revenue given pest management with that experienced for conventional pest control.
Differences in yield greater than that break-even increase were observed on the experimental pest management orchard in 1977, suggesting that employment of the program could result in an increase in net returns of up to 75 percent more than those received using conventional control. Since yield differences between the experimental orchards

could not positively be attributed to the pest control method utilized, uncertainty regarding the profitability of the pest management program still exists.

The static pecan price impacts of an average regional change in pecan yield equal to the break-even yield increase estimated for an individual pecan grower at actual 1977 prices was estimated using coefficients of a price prediction model. A price decrease of approximately one cent per pound of pecans under that observed in 1977 was estimated to have resulted if all Southeastern pecan growers had employed pest management and had experienced yield increases of that magnitude.

Widespread adoption of the multi-pest management program would significantly reduce the quantity of pesticides applied topically to pecans and would decrease the environmental load of and risk of human exposure to typically used insecticides.

PRODUCTION AND COST IMPLICATIONS OF A MULTI-PEST MANAGEMENT PROGRAM FOR PECANS

Katherine H. Reichelderfer
Agricultural Economist

Introduction

A team of researchers at USDA's Southern Fruit and Tree Nut Research Station in Byron, Georgia have developed and conducted a three-year field test of a multi-pest management program for pecan production. The primary objective of the pest management project was to decrease the number of foliar sprays of pesticides on pecans. This was seen as a means for obtaining pesticide and management cost savings and as a method for decreasing exposure to pesticides.

This report summarizes an evaluation of the production and cost impacts of substituting the pest management program for conventional control practices on the experimental acreage in Georgia and examines the economic implications of widespread adoption of the experimental program throughout the Southern U.S.

The objectives of the economic evaluation were:

1. To determine the effect of pest control methods on expected pecan yield.
2. To compare cost differences for the two pecan pest control methods tested in Georgia.
3. To estimate the expected value to producers of adopting the multi-pest management scheme as opposed to using conventional control.

4. To estimate the static impact of a regional adoption of the multi-pest management program on pecan price and total net revenue of producers in the Southern U.S.

Background

Pecans are a high valued commodity. Although they are not considered a major domestically produced commodity, the value of U.S. pecan production in 1977 exceeded 136 million dollars (5). Table 1 shows the level of production of pecans (all varieties) by State. Georgia has historically been the major pecan producing State and has continued, in recent years, to produce from 30 to 50 percent of total U.S. pecans. Over the three-year period 1975-1977, three Southeastern States, Georgia, Alabama, and Florida, accounted for approximately one half of total U.S. pecan production (Table 1). The following discussion of pecan production and pest control will focus on Southeastern pecans.

Entrance into pecan production is a long-term prospect. Pecan trees typically do not bear a significant crop until they are 10-15 years old, depending upon the variety grown. Alternate year bearing is characteristic of pecans. A year during which yield is above average is frequently followed by a year for which yield is below average. This results in great variability in expected income from year to year. There is reason to believe that proper overall management of pecan trees may tend to decrease the variation in yield between years.

Pests pose a major problem to producers of pecans. A given variety of pecans may be susceptible to any of ten different diseases and attack by ten insect pests of economic importance. In Georgia and most of the Southeast,

Table 1. Pecan Production by state, 1975-1977

State	Production (1,000 pounds)		
	1975	1976	1977
Alabama	20,000	5,000	32,000
Arkansas	3,500	1,000	3,000
Florida	5,000	2,500	6,100
Georgia	75,000	52,000	88,000
Louisiana	32,000	2,000	31,000
Mississippi	6,000	1,500	11,000
New Mexico	13,100	11,500	15,000
No. Carolina	2,200	2,800	2,000
Oklahoma	20,000	2,300	13,500
So. Carolina	2,000	2,500	3,000
Texas	68,000	20,000	32,000
U.S. Total	246,800	103,100	236,000

Source: U.S. Department of Agriculture; Economics, Statistics and Cooperatives Service; Crop Reporting Board. Noncitrus Fruits and Nuts: Midyear Supplement. July 1978.

the most destructive pest is pecan scab, a fungus disease. Insects of primary importance include hickory shuckworms, the pecan weevil, leaf and nut casebearers, yellow aphids, black pecan aphids, spittlebugs and spider mites.

Current recommended (conventional) control of pecan pests in Georgia involves a schedule of up to 16 separate foliar applications of pesticides. This schedule is shown in Table 2 and includes eight intraseasonal applications of parathion, malathion, guthion, phosolone or carbaryl against lepidopterous larvae, aphids, mites, and spittlebugs, and one to five or more applications of carbaryl or guthion plus toxaphene to control the pecan weevil (3).

The multi-pest management program developed and tested in Georgia substitutes blacklight traps (two per acre) for insecticides to control lepidopterous pests. It substitutes a soil systemic insecticide (applied only once at beginning of season) for foliar sprays to control spittlebugs, aphids, and mites. A soil fumigant (EDB) was applied the first year of the project as a long-term (3 year) substitute for foliar sprays to control the pecan weevil. A last difference is that the number of fungicide applications was reduced to four and the quantity of fungicides applied per application was doubled for the pest management experiment (for detailed information see Gentry et. al.).

The pest management experiment was conducted in a 50 year old orchard for which management practices had been at a minimum level for a number of years. In 1974, the year before the project was initiated, the pecan trees were bearing no marketable yield. Two plots of approximately 50 acres each were chosen for the experiment. The plots were not contiguous.

Table 2. Recommended schedule for control of pecan pests in Georgia

Spray time of application	Pest(s) to control	Spray materials per acre for medium-sized trees in 60 foot rows
First Prepollination Spray - when buds being to open	scab leaf case-bearer	Dodine (65% WP, 2 lbs.), Fentin hydroxide (50% WP, 0.8 lb.), or Benomyl (50% WP, 0.8 lb.) for scab PLUS Parathion (15% WP, 4 lbs.) or Malathion (25% WP, 6 lbs.) for leaf casebearer
Second Prepollination - Spray - two weeks after first spray	scab spittlebugs	Same choice of chemicals and same rate as above for scab control PLUS Carbaryl (80% WP, 3 lbs.), Parathion (15% WP, 4lbs.), Guthion (50% WP, 2 lbs.) or Phosolone (25% WP, 4 lbs.) if spittle-bugs are a probelm
First Cover Spray - when yound nuts first appear	scab nut case-bearer mites aphids	Same choice of chemicals and same rate as above for scab control PLUS Parathion (15% WP, 4 lbs.), Malathion (25% WP, 6 lbs.) or Phosolone (25% WP, 4 lbs.) - to be applied again one week later if casebearer problem severe
Second Cover Spray - three weeks after first cover spray	scab powdery mildew	Dodine (65% WP, 2 lbs.), Fentin hydroxide (50% WP, 0.8 lb.), or Benomyl (50% WP, 0.8 lb.), for scab and mildew An additional application of Phosolone may be made at this time if aphids and mites require more control
Third Cover Spray - two to three weeks after second cover spray	scab powdery mildew downy spot brown leafspot	Same choice of chemicals and same rate as above for scab and mildew control
Fourth Cover Spray - two to three weeks after third cover spray	scab powdery mildew downy spot brown leafspot	Same choice of chemicals and same rates as above for scab and mildew control
Pecan Weevil Sprays - every 7 days from the time that shells begin to harden (Aug. 10-15) until Mid-September or later if adult weevils are still present	pecan weevils shuckworms	Carbaryl (80% WP, 3lbs.) or a mixture of Toxaphene (40% WP, 12 lbs.) and Guthion (50% WP, 2 lbs.)
Fifth Cover Spray - two to three weeks after fourth cover spray	scab powdery mildew downy spot brown leafspot	Same as second cover spray, including additional application of Phosolone for mites or aphids if necessary
Sixth Cover Spray - two to three weeks after fifth cover spray	scab black aphid schuckworm	Same as bove

Source: Pecan Insects and Diseases and Their Control, Cooperative Extension Service, Univ. of Georgia, College of Agriculture, Bulletin 644, Athens, 1975.

Both experimental orchards had a mixed planting of Stuart and Schley pecan varieties but the proportion of trees of a given variety within plots varied between the two orchards. The two experimental orchards received identical fertilizer and herbicide applications. Only the method of treatment for insect pests and fungus diseases differed between the plots. Orchard A was the multi-pest management program plot. Orchard B was treated using conventional pest control. The calendar of events in 1977, shown in Table 3, illustrates the differences in the pest control methods used in the experimental orchards.

Conventional Spray versus Multi-pest Management Program for Control of Pecan Pests

A combination of two primary factors determines the profitability and relative attractiveness to the pecan grower of the multi-pest management program. These are: (1) effects on yield, and (2) changes in cost associated with the substitution of the pest management for the conventional pest control program. Estimates of yields and costs were based on experimental data and costs experienced by the researchers who conducted the experiment described above.

Yield differences:

Yield data were collected for a sample of approximately ten percent of the trees in each experimental orchard. Table 4 shows the mean and standard deviation of yield for the sampled trees in each orchard over the three-year experimental period. Populations of trees were classified by variety so that varietal effects on mean yield could be separated from other effects. Several observations may be made from Table 4. First, mean yield in

Table 3. Calendar of pest control events, 1977

Orchard	Treatments	Date(s)
Pest Management Program (Orchard A)	22-watt circline blacklight traps (2/acre)	energized: March 15
	Soil systemic insecticide-aldicard (Temik)	applied: May 1
	Soil fumigant-ethylene dibromide (EDB)	applied: May 15, 1975
	Fungicides-benomyl (Benlate) plus fentin hydroxide (Du-ter)	applied: April 5 May 11 June 15 July 21
Conventional Spray Program (Orchard B)	Phosalone (Zolone) for shuckworm, aphid, mite and spittlebug control	applied: May 3 June 15 June 28 Sept. 15
	Dialifor (Torak) for pecan weevil control	applied: August 9 August 17 Sept. 6
	Carbaryl (Sevin) for pecan weevil control	applied: August 25
	Fungicides-benomyl (Benlate) plus fentin hydroxide (Du-ter)	applied: April 5 April 19 May 3 May 25 June 15 June 28 July 21 August 9

Table 4. Mean yield and standard deviation of yield for experimental pecan orchards, 1975-1977

	Number of observations (trees)	1975 Mean yield (lbs/tree)	1975 Standard deviation of yield	1976 Mean yield (lbs/tree)	1976 Standard deviation of yield	1977 Mean yield (lbs/tree)	1977 Standard deviation of yield
Orchard A a/							
Total	39	37.1	18.6	80.8	38.4	154.3	58.3
Stuart variety	27	44.3	18.1	96.7	33.0	168.5	58.2
Schley variety	12	20.8	2.5	44.9	22.2	122.5	46.2
Orchard B b/							
Total	41	35.9	26.2	68.2	53.1	89.2	64.3
Stuart variety	20	44.9	33.2	99.3	59.5	114.5	61.9
Schley variety	21	27.3	12.9	38.5	19.4	65.2	58.2

a/ Treated as per multi-pest management procedures.

b/ Treated conventionally.

c/ Fertilizer and herbicide application rates and mowing practices were identical for the two orchards.

orchard A was higher and the standard deviation of yield in orchard A was lower than for orchard B for each year. However, mean yield differences by pecan variety, in years 1975 and 1976 are trivial. Secondly, average yield per tree increased yearly for each orchard and each variety over the three-year period. This most likely reflects a recovery of the orchards resulting from improved management. However, the consistent increases in mean yield may mask the commonly observed alternate year bearing patterns and make it difficult to assess effects on year-to-year variance in yield.

The average gains in pecan yield per tree between the first and second and the second and third years of the experiment are shown in Table 5. Orchard A had greater increases in mean yield between years than orchard B.

An analysis of variance was conducted to determine whether mean yields (within and between years) in orchards A and B differed significantly. Fisher's F-distribution was employed to test the null hypothesis that there was no difference between mean yields. Tables 6 and 7 summarize the results of the analysis of variance. The null hypothesis was supported within years 1975 and 1976 and between years 1975-76. The null hypothesis was rejected within 1977 and between 1976-77. A significant difference, at the 0.01 level, was indicated. Results suggest that the experimental treatments may have produced the yield differences observed in 1977. The significantly lower increases in yield, 1976-77, observed in orchard B could be a reflection of the alternate bearing trend typical of pecans and indicate that the pest management treatment prevented a similar reduction in yield gain between years on orchard A. Unfortunately, the experiment was not designed in such a way to permit definitive conclusions.

Table 5. Between-year differences in mean yield for experimental pecan orchards

	Yield difference 1975-1976		Yield difference 1976-1977	
	Mean	Standard deviation	Mean	Standard deviation
	(lb./tree)		(lb./tree)	
Orchard A				
Total	43.7	29.7	73.6	45.0
Stuart variety	52.4	28.4	71.8	48.6
Schley variety	24.1	23.2	77.6	37.1
Orchard B				
Total	32.3	43.1	22.2	69.9
Stuart variety	54.4	50.0	17.7	79.8
Schley variety	11.2	19.5	26.5	60.6

Table 6. F-statistics a/ obtained for comparison of pecan yields in orchards A and B b/, 1975-1977

	Item	1975 - Orchard A: Total	1975 - Orchard A: Stuart variety	1975 - Orchard A: Schley variety	1976 - Orchard A: Total	1976 - Orchard A: Stuart variety	1976 - Orchard A: Schley variety	1977 - Orchard A: Total	1977 - Orchard A: Stuart variety	1977 - Orchard A: Schley variety
1975 Orchard B	Total	.055 (F=6.96)								
	Stuart variety		.006 (F=7.225)							
	Schley variety			2.913 (F=7.53)						
1976 Orchard B	Total				1.468 (F=6.96)					
	Stuart variety					.036 (F=7.225)				
	Schley variety						.748 (F=7.53)			
1977 Orchard B	Total							22.42 (F=6.96)		
	Stuart variety								9.363 (F=7.225)	
	Schley variety									8.521 (F=7.53)

a/ Degrees of freedom equaled 1/78 for comparison of totals, 1/45 for comparison of Stuart varieties, and 1/31 for comparison of Schley varieties; critical values of F at the 95 percent significance level (99 percent significance level) equal 3.96 (6.96), 4.055 (7.225), and 4.16 (7.53) for 1/78, 1/45, and 1/31 degrees of freedom, respectively.

b/ Orchard A was treated as per pest management procedures; orchard B received conventional control.

Table 7. F-statistics a/ obtained for comparison of between year pecan yield differences in orchards A and B b/

Item		Orchard A, 1975-1976			Orchard A, 1976-1977		
		Total	Stuart variety	Schley variety	Total	Stuart variety	Schley variety
	Total	1.88 (F=6.96)					
Orchard B 1975-1976	Stuart variety		.030 (F=7.225)				
	Schley variety			2.89 (F=7.53)			
	Total				15.125 (F=6.96)		
Orchard B 1976-1977	Stuart variety					8.286 (F=7.225)	
	Schley variety						6.99 (F=7.53)

a/ Degrees of freedom equaled 1/78 for comparison of totals, 1/45 for comparison of Stuart varieties, and 1/31 for comparison of Schley varieties; critical values of F at the 95 percent significance level (99 percent significance level) equal 3.96 (6.96), 4.055 (7.225), and 4.16 (7.53) for 1/78, 1/45, and 1/31 degrees of freedom, respectively.

b/ Orchard A was treated as per pest management procedures; orchard B received conventional control.

Since only two plots were chosen for the experiment, the differences in mean yields between plots could have been the result of environmental factors unrelated to the method of pest control. Proof of significant difference cannot also be interpreted as proof of cause and effect. A regression analysis was attempted in an effort to explain the differences in mean yields. Its results (see Appendix I) were inconclusive. Since the observed, significant differences in mean yields could not readily be explained, uncertainty regarding the effect of the multi-pest management program on pecan yield still exists. To remove this uncertainty, the experiment should be redesigned to separate pest control effects from other potential factors of yield variation and to provide explanatory data. A general statement on what is needed to verify analysis of variance results is presented in Appendix II.

Even while accounting for qualification of analysis of variance results, it seems reasonable to assume that the difference in experimental treatment explains the observed difference in pecan yields in 1977. For two years prior to 1977, mean yields did not differ significantly between orchards. That lack of difference may rule out constant environmental differences between orchards.

Assuming that the difference in mean yields between experimental orchards in 1977 resulted from the method of pest control, with the use of the multi-pest management scheme, it may be possible to obtain up to a 47 percent increase in average yield of Stuart and up to an 88 percent increase in average yield of Schley variety pecans.

Cost differences:

The per acre costs of employing the multi-pest management program exceeded the per acre costs of conventional pest control on the experimental pecan orchards. Tables 8 and 9 list the average pest control costs for each of the orchards in 1977. Fuel and labor costs were 75 percent higher for conventional control than for pest management. However, the additional material and equipment costs required for implementation of the multi-pest management program override labor and fuel cost savings.

Net revenue for pest management versus conventional control:

Net revenue is a function of yield, pecan price, and the total cost of production. The total cost of pecan production is, in turn, a function of pecan yield where custom harvesting is employed and of pecan price and yield where management costs are included.

Total costs of pecan production in Georgia (excluding overhead, land rent, and risk) are the sum of all preharvest variable costs, ownership (of machinery) costs, harvest costs, and a management charge. The sum of 1977 average preharvest and ownership costs for pecan production under the multi-pest management program and assuming a 400 acre operation was calculated from cost data provided by the researchers in Georgia and equaled 259 dollars per acre. The same sum given conventional control of pecan pests equaled 203 dollars per acre. Custom harvest costs equal approximately 15 cents per pound of pecans. Management costs are assumed to equal approximately seven percent of gross receipts. The total costs (excluding land, overhead, and risk) of producing pecans in Georgia under the two different pest control strategies equal:

Table 8. Pecan pest control budget given the multi-pest management scheme, 1977 (per acre)

Pest control input or activity	Unit	Cost per Unit	Average rate per acre	Average cost per acre
		(dol.)	(per year)	(dol./year)
Variable costs:				
Herbicide materials a/	appl.	6.78	2.0	13.56
Fungicide materials:				
Fentin hydroxide (Du-ter)	lbs.	6.65	2.64	17.56
Benomyl (Benlate)	lbs.	6.95	2.64	18.35
Insecticide materials:				
EDB b/	gal.	6.35	1.68	10.67
Aldicarb (Temik) c/	lbs.	1.40	42.00	58.80
Herbicide application:				
Labor	hrs.	3.00	0.72	2.16
Fuel (gasoline)	gal.	0.48	0.22	0.10
Fungicide application:				
Labor	hrs.	3.00	1.20	3.60
Fuel (diesel)	gal.	0.42	7.56	3.18
Fuel (gasoline)	gal.	0.48	2.40	1.15
Insecticide application:				
Labor b/	hrs.	3.00	0.96	2.88
Fuel (gasoline)	gal.	0.48	0.43	0.21
Black light traps: d/				
Maintenance and repairs				25.00
Electrical power	kw-hrs.	0.04	150.00	6.00
Total variable costs				163.22
Ownership costs: e/				
Sprayers				9.19
Tractors (to pull sprayers)				5.43
Grain drill				1.44
Black light traps				25.40
Total ownership costs				41.46
Total pest control costs				204.68

a/ As neither the type nor rate of application of herbicide materials varied between experimental orchards, herbicide materials were considered a single input for this analysis and the various materials used are not specified here.

b/ EDB was applied at a rate of five gallons per acre in 1975. The rate of application was divided by three to obtain an average rate and cost for this 1977 budget.

c/ Experimental use permit no. 11312-4.

Table 9. Pecan pest control budget given conventional control practices, 1977 (per acre)

Pest control input or activity	Unit	Cost per unit (dol.)	Average rate per acre (per year)	Average rate per acre (dol./year)
Variable costs:				
Herbicide materials a/	appl.	6.78	2.0	13.56
Fungicide materials:				
Fentin hydroxide (Du-ter)	lbs.	6.65	2.64	17.56
Benomyl (Benlate)	lbs.	6.95	2.64	18.35
Insecticide materials:				
Phosolone (Zolone)	pts.	2.025	16.20	32.80
Dialifor (Torak)	pts.	2.36	10.44	24.64
Carbaryl (Sevin)	lbs.	1.34	5.21	6.98
Herbicide application:				
Labor	hrs.	3.00	0.72	2.16
Fuel (gasoline)	gal.	0.48	0.22	0.10
Fungicide and insecticide application: b/				
Labor	hrs.	3.00	3.60	10.80
Fuel (diesel)	gal.	0.42	17.52	7.36
Fuel (gasoline)	gal.	0.48	5.40	2.59
Total variable costs				136.90
Ownership costs: c/				
Sprayers				9.19
Tractors (to pull sprayers)				5.43
Total ownership costs				14.62
Total pest control costs				151.52

a/ As neither the type nor rate of application of herbicide materials varied between experimental orchards, herbicide materials were considered a single input for this analysis and the various materials used are not specified here.

b/ Six of eight insecticide treatments were applied in conjunction with fungicides. Therefore, application costs for the two types of pesticides were combined for presentation in this budget.

c/ Assuming an average orchard size equal to 400 acres.

$$C_A = \$259.00 + 0.15\ Y_A - 0.07\ PY_A$$

$$C_B = \$203.00 + 0.15\ Y_B - 0.07\ PY_B$$

where: C_A = total per acre cost given pest management

C_B = total per acre cost given conventional control

Y_A = average pecan yield (pounds per acre) given pest management

Y_B = average pecan yield (pounds per acre) given conventional control

P = price per pound of pecans (received by farmers)

Average returns to pecan production under the two pest control strategies equal:

$$R_A = PY_A - \$259.03 - .15\ Y_A - .07\ PY_A$$

$$= (.93P - .15)\ Y_A - \$259.03$$

$$R_B = PY_B - \$203.04 - .15\ Y_B - .07\ PY_B$$

$$= (.93P - .15)\ Y_B - \$203.04$$

where: R_A = average per acre returns to land, overhead, and risk given pest management

R_B = average per acre returns to land, overhead, and risk given conventional control

The average yield required to equate net revenue given employment of the multi-pest management program with that obtained with conventional control is the following function of pecan price:

$$Y_A = Y_B + \frac{259.03 - 203.04}{(.93P - .15)}$$

Using this equation, and substituting 1977 pecan prices for P, an average increase of approximately 102 pounds per acre of Stuart or 87 pounds per acre of Schley pecans over that yield obtained using conventional pest control would be required to equate average net returns to the use of the two pest control strategies.

In 1977, the experimental pest management orchard yields exceeded the required break-even increase. Tables 10 and 11 summarize the production and cost situation experienced in 1977 given the assumption of an equal mix of Stuart and Schley varieties, 12 trees per acre on a 400 acres operation at 1977 prices. These budgets are not representative of expected costs and returns. They merely express the observed costs and returns to the two experimental plots and show that net returns on the orchard utilizing pest management were, for one year only, considerably higher than for the conventionally treated orchard.

Table 10. Pecan production budget: multipest management scheme

Item	Unit	Average price or cost per unit	Quantity	Value or cost per acre	Cost per unit of production
		dol.		dol.	dol.
Gross receipts					
Pecans	lbs.	0.80	1,746.0	1,396.80	
Total receipts				1,396.80	
Variable costs:					
Preharvest:					
Fertilizer	lbs.	0.074	360.0	26.64	0.02
Herbicide materials	appl.	6.78	2.0	13.56	0.01
Insecticide materials	appl.	52.23	1.33	69.47	0.04
Fungicide materials	appl.	9.00	4.0	36.00	0.02
Machinery labor	hrs.	3.00	7.78	23.33	0.01
Tractor fuel	gals.	0.44	8.4	3.70	0.00
Sprayer fuel	gals.	0.42	7.56	3.18	0.00
Electric power	kwhrs.	0.04	150.0	6.00	0.00
Black light trap maintenance				25.00	0.01
Total preharvest	dols.			206.88	0.12
Harvest:					
Custom harvesting	lbs.	0.12	1,746.0	209.52	0.12
Custom cleaning	lbs.	0.03	1,746.0	52.38	0.03
Total harvest	dols.			261.90	0.15
Total variable costs	dols.			468.78	0.27
Income above variable costs				928.02	0.53
Ownership costs (depreciation, taxes, interest, insurance)					
Tractors				12.89	0.01
Sprayers				9.19	0.01
Equipment				4.67	0.00
Black light traps (2 per acre)				25.40	0.01
Total ownership costs				52.15	0.03
Management charge (7.0 % of gross receipts)				97.78	0.06
Total of above costs				618.71	0.35
Return to land, overhead and risk				778.09	0.45

Table 11. Pecan production budget: conventional control of pests

Item	Unit	Average price or cost per unit	Quantity	Value or cost per acre	Cost per unit of production
		dol.		dol.	dol.
Gross receipts:					
Pecans	lbs.	0.80	1,071.0	856.80	
Total receipts				856.80	
Variable costs:					
Preharvest:					
Fertilizer	lbs.	0.074	360.00	26.64	0.02
Herbicide materials	appl.	6.78	2.0	13.56	0.01
Insecticide materials	appl.	8.04	8.0	64.32	0.06
Fungicide materials	appl.	4.52	8.0	36.19	0.03
Machinery labor	hrs.	3.00	8.16	24.48	0.02
Tractor fuel	gals.	0.45	11.49	5.17	0.00
Sprayer fuel	gals.	0.42	17.54	7.37	0.01
Total preharvest:	dols.			177.73	0.16
Harvest:					
Custom harvesting	lbs.	0.12	1,071.0	128.52	0.12
Custom cleaning	lbs.	0.03	1,071.0	32.13	0.03
Total harvest:	dols.			160.65	0.15
Total variable costs:				338.38	0.31
Income above variable costs				518.42	0.49
Ownership costs (depreciation, taxes, interest, insurance)					
Tractors				12.89	0.01
Sprayers				9.19	0.01
Equipment				3.23	0.00
Total ownership costs				25.31	0.02
Management charge (7 % of gross receipts)				59.98	0.06
Total of above costs				423.67	0.40
Return to land, overhead and risk				433.13	0.40

Given either the assumption that the difference in experimental treatment explained the observed difference between yields in the experimental orchards, or that employment of the multi-pest management program would increase average pecan yield per acre by the required break-even amount, it can be concluded that the pest management strategy developed in Byron. Georgia is competitive with or more profitable than conventional control of pecan pests. The validity of the assumptions on which that conclusion is based is currently unknown but could be determined through continued experimentation. As there is some uncertainty with the tentative conclusions presented above, proof that the multi-pest management program is currently ready for adoption does not exist. The suggestion that it may be a profitable alternative, however, lends value to continued experimentation and justifies an examination of some impacts of its widespread adoption.

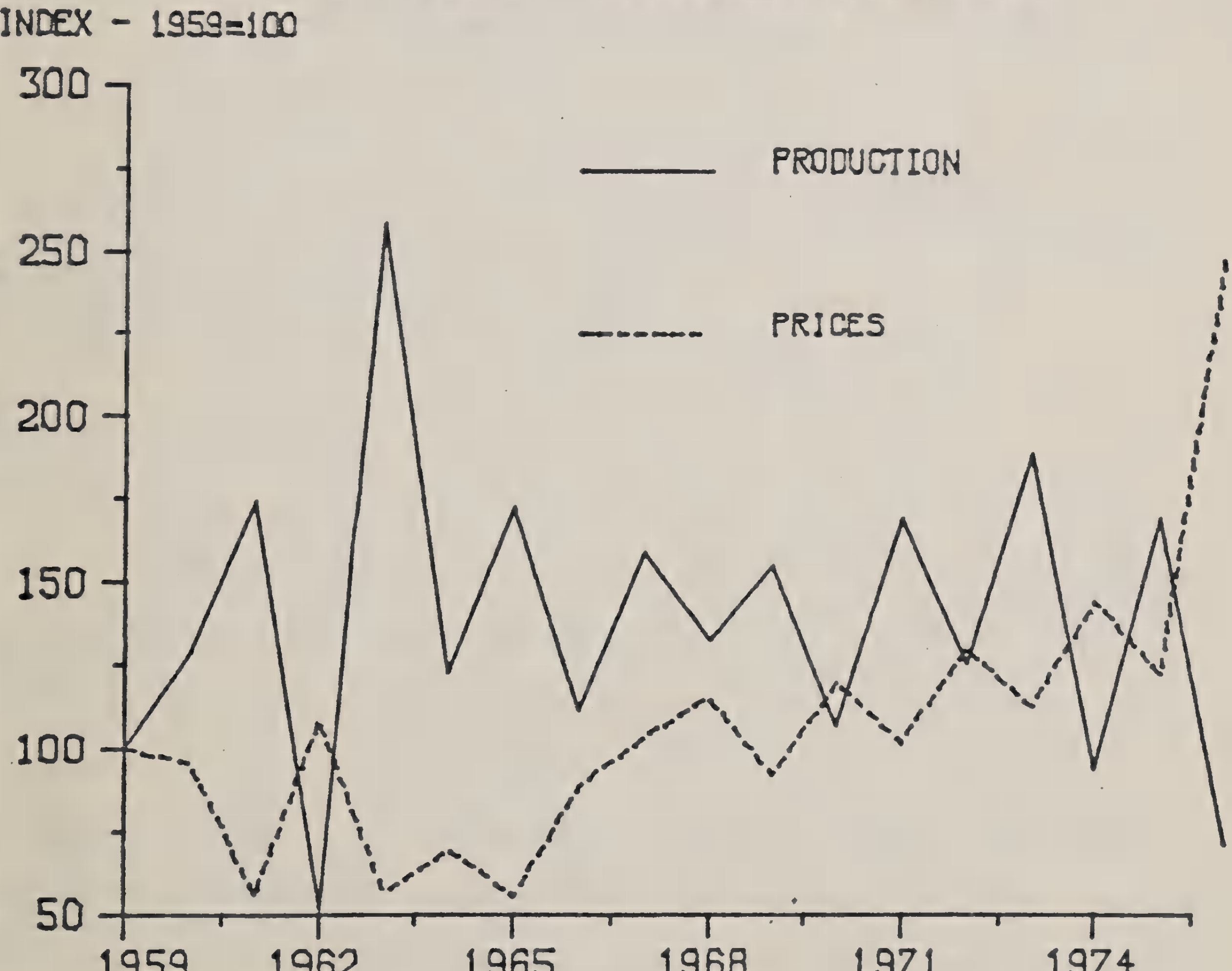
Pecan Price Impacts of Adoption of the Pest Management Program

Widespread adoption of yield increasing technology impacts upon the price of the commodity for which average yield rises. Pecan price is fairly sensitive to the total available supply of pecans. Figure 1 illustrates the trends of U.S. pecan production and prices over time and indicates a definite negative relationship between the two variables.

Fowler (1) developed a statistical model of the following form to predict the farm price of pecans as a function of income, a time trend, the lagged farm-wholesale price margin and total supply of pecans.

FIGURE 1.

U.S. PECAN PRODUCTION AND PRICES



SOURCE - AGRICULTURAL STATISTICS, 1977.

$$P_t = a + b_1 I + b_2 T_t + b_3 M_{t-1} + b_4 S_t + U_t$$

where: P_t = U.S. average annual price received by growers for all pecans (cents per pound), deflated by the CPI

I_t = index of disposable income per capita, deflated by the CPI

T_t = time in years

M_{t-1} = farm-wholesale price margin lagged one year

S_t = production in pounds per capita

U_t = an unobserved residual variable

Fowler's regression analysis of factors affecting pecan prices received by farmers resulted in the following equation:

$$P_t = 016.770 + .572\ I_t - 1.194\ T_t - 16.321\ S_t + .36\ M_{t-1}$$

$$(R^2 = 0.83)$$

The coefficient attached to Fowler's supply variable indicates that, all else equal, each increase of 0.1 pound per capita of pecans would decrease the price per pound of pecans by 1.6 cents. The extent to which the per capita supply of pecans could increase is a function of the number of growers who, at a given time, adopt a yield increasing technology. Widespread adoption of the relatively costlier and, possibly, more efficacious pecan pest management strategy could have either a positive or negative impact on pecan growers' net revenues. The degree to which adoption would

affect pecan price, and growers' resultant net revenues, depends upon the extent of adoption and on the yield impact of the substitution of pest management for conventional control.

An individual pecan grower's net revenue given no adoption of pest management is equal to:

$$PY - C$$

where: P = pecan price in cents per pound

Y = pecan yield in pounds

C = cost of pecan production

If a number of growers had adopted the pest management program, an individual adopter's net revenue is, instead, equal to:

$$(P - 16.32S^*)\ (Y + I) - (C + 56.00 + H)$$

where: S^* = change in U.S. pecan production, pounds per capita, resulting from adoption of the pest management technology by some growers

I = increase in individual's pecan yield resulting from his adoption of the pest management technology

H = increase in harvest and management costs resulting from increased yield of pecans

The equation may be rewritten as:

$$PY - C + PI - 16.32SY - .1632SI - 56.00 - H$$

The first two variables in the reexpressed equation are equivalent to the net revenue to be obtained by a grower when no adoption of the pest management technology takes place. Therefore, the interaction of the last five variables in the equation determines the difference between net revenue in the absence and presence of pecan pest management adoption. In order for

net revenue to be greater than or equal to that obtained when there is no use of the new pest management technology, the original pecan price times the addition to yield resulting from implementation must be greater than or equal to the change in pecan price times total yield given implementation plus the additional costs of production given pest management.

First adopters, whose changes in yield would have no measurable effect on the total per capita supply of pecans, or hence on pecan price, could realize increases in net revenue if the pest management program does, in fact, increase yield by enough to cover increased costs. As adoption becomes more widespread, a point could be reached where increases in pecan supply result in a decrease in pecan price that would override the value of individuals' increases in yield

Fowler's model was used to predict the static impact on pecan price of the adoption of the multi-pest management program for pecan production throughout the States of Georgia, Alabama, and Florida. The prediction was made under the following assumptions:

1. Yield was assumed to be an estimation of supply. (As short-term changes in pecan acreage are minimal, this is not unreasonable.)
2. Average pecan yield for all Georgia, Alabama, and Florida acreage was assumed to increase by a percentage equal to that required for the experimental pest management program to yield the same net returns per acre as did the use of conventional control in 1977.

3. An equal mix of Stuart and Schley varieties was assumed to represent average pecan plantings in the Southwestern U.S.

Based on experimental data, a nine percent proportional increase in yield on the pest management experimental acreage in relation to conventionally treated acreage in 1977 would have equated net returns. This assumes an equal mixed planting of Stuart and Schley pecans. If, in 1977, the total yield of pecans from Georgia, Alabama, and Florida had increased by 9 percent, the total U.S. supply of pecans would have been 4.8 percent higher. Per capita supply of pecans would also have been 4.8 percent greater than the 1.05 pounds per person actually produced in 1977. Under the scenario described above, the average U.S. 1977 pecan price received by farmers would have been approximately one cent per pound lower than that observed in 1977.

The implication of the short-run difference in pecan price is that, given the assumptions discussed above, the pecan price would have dropped to a point where realized average net revenue employing pest management would have been $10 to $15 per acre lower than that using conventional control. The negative effect of pecan price on net revenue would have overridden the positive effect of an increase in average yield. The net revenue of growers in other regions would also have been adversely affected by the relatively lower pecan price. However, realistic predictions of the impact of adoption on pecan price cannot be made unless the explicit relationship between pecan pest control method and pecan yield can be identified.

Pesticide Use Impacts of Widespread Adoption of the Pecan Pest Management Program

The primary objective of the multi-pest management program for pecans was to reduce the number of foliar sprays applied to the trees. Although achievement of that objective did not, in 1977, result in production cost savings, it did significantly reduce the potential environmental and human hazards associated with pecan insect pest control.

The only insecticide applied to the pest management experimental orchard in 1977 was aldicarb. The chemical was applied to the soil and, as a systemic treatment, was less apt to come in contact with nontarget species or persons working in the orchard than would typically applied substances.

One of three relatively broad spectrum insecticides, phosolone, dialifor, and carbaryl, was applied to the conventional control experimental orchard on eight separate occasions. Carbaryl is used extensively on a variety of other crops in the Southeast. In 1976, 3,577,727 pounds of carbaryl were applied to field crops alone in the Southeast (4). Use of the chemical on pecans adds to the environmental load of that material in the region.

The widespread substitution of pest management for conventional control of pecan insects could significantly reduce the quantity of insecticides applied, and any environmental or human health hazards that may be associated with their use, in the Southern U.S.

Summary and Conclusions

A pecan pest management program that substituted one soil fumigation treatment every three years, a systemic insecticide application and black

light traps for intraseasonal foliar sprays against insects, and in which the number of fungicide applications was reduced, was developed by USDA researchers in Byron, Georgia. The program was tested for three years in the field. One experimental pecan orchard was treated using the newly developed pest management procedures. Another plot of roughly equal size was treated conventionally for pecan pests. Data on yield and levels of pest infestation were collected from sampled trees in each of the two orchards.

Cost and production impacts of the pest management program were estimated from experimental data. Conclusions drawn from the comparison of yield and cost data from the experimental orchards included:

1. Only in 1977 were there significant yield differences between experimental orchards. In 1977, the mean yield of sampled Schley variety trees was 88 percent greater and of sampled Stuart variety trees was 47 percent greater in the pest management orchards than in the conventionally treated orchard.
2. At 1977 prices, the cost of the pest management program exceeded the cost of conventional pest control by approximately $56.00 per acre.
3. At 1977 prices, and taking all harvest and preharvest costs into account, a break-even yield increase of 102 pounds per acre of Stuart or 87 pounds per acre of Schley pecans would be required to equate an individual's expected net revenue given pest management with that experienced with conventional control.

4. More than the required break-even yield differences were observed between experimental plots in 1977. Average net returns of approximately $345.00 per acre higher were realized on the pest management than on the conventionally treated orchard. However, the experiment was not designed so that the total difference in net returns could be conclusively attributed to the difference in pest control treatment.

Results of the evaluation of cost and production impacts of the pest management program to individual pecan growers at constant 1977 prices were extended to examine possible impacts of widespread adoption of the program. The assumptions were made that all Southeastern pecan growers adopted the pest management program and realized yield increases equal to the average per acre estimated break-even yield, and that pecan price was variable rather than constant. The estimated impact of the increased supply of pecans was a one cent per pound decrease in the average price received for pecans. Under conditions of widespread (complete) adoption, the producers would have achieved lower net revenues per acre given pest management than they did employing conventional control in 1977.

Field tests of the multi-pest management program for pecans indicate that employment of the strategy could increase first adopters' net revenues to pecan production. More conclusive yield data are required before realistic, rather than hypothetical, pecan price and production impacts of widespread adoption of the pest management program can be estimated.

Appendix I: Linear Regression Estimation of a Production Function for Pecans

The discovery of significant differences between experimental orchards' mean pecan yields in 1977 implied, but could not prove the existence of a causal relationship between pecan yield and the pest control practices employed. A regression analysis was therefore conducted in an attempt to identify the factor or factors that explained the observed pecan yield differences.

Linear regression was used to estimate a production function for pecans with respect to pest control and all other measurable inputs and production conditions. The estimation of a reliable production function would have allowed for the separation of the effect of pest control action on yield from all other factors that may have contributed to observed variations in yield. Unfortunately, experimental data were inadequate to obtain significant results. In the analysis it was assumed, first, that pecan yield per tree is some function:

$$Y = f\,(F, W, C_1, C_2 \ldots, C_n, P_1, P_2, \ldots P_n, L, M, G, K, E_1, E_2, \ldots E_n, Y_{t-1}, F_{t-1})$$

Where: $Y=$ yield

$F=$ fertilizer applied

$W=$ diameter of tree trunk

C_i = pest control action i

P_i = indicator of pest problem
(number of pest i, number of nuts infested by pest i, etc.)

L = labor inputs

M = management inputs

G = fuel inputs

K = machinery inputs

E_i = environmental variable i

Y_{t-1} = yield in the previous year

F_{t-1} = fertilizer applied in previous year

Each bit of required data was available from 19 Stuart variety and 8 Schley variety trees in orchard A and from 12 Stuart variety and 15 Schley variety trees in orchard B, for each year 1975-1977. The 162 observations from Those 54 trees made up the samples from which the prodcution function was to be estimated.

For each pest control action that utilized chemical inputs, the quantity applied within a given season was used as the variable expressing that action. An exception to that was treatment with EDB. A dummy variable was used to specify whether or not a given tree had been treated with EDB in 1975. A dummy variable was also used to indicate whether or not a given tree was in orchard A, thus accounting for the use of blacklight traps.

Indicators of pest problems observed for each tree in the sample were:

(1) percent of shucks infested with hickory shuckworm
(2) number of webworm webs per tree
(3) number of yellow aphids per 50 leaflets
(4) honeydew rating
(5) number of black pecan aphids per 50 leaflets
(6) number of damaged leaflets per 50 leaflets
(7) number of mines per 50 leaflets
(8) number of spittlebug masses per 20 terminals
(9) number of mites per 50 leaflets
(10) percent infestation by weevils
(11) percent commercial control of scab
(12) percent of scab free nuts

Total seasonal inches of rain and inches of rainfall received at two different critical times were used as environmental variables.

A number of the variables in the generalized equation above are obviously related to one another. For example, a given pest control action will directly influence the observed numbers of pests per tree. To avoid the problem of multicollinearity, different subsets of the set of original variables were used in the estimation procedure.

Since variety exerts a considerable influence on pecan yield, varieties were separated for the analysis. Regressions of various factors on Schley yield and on Stuart yield were made independently.

As the number of possible factors considered was very large and the significance of any given variable was not known, a stepwise regression technique was utilized.

A total of 12 stepwise regressions were run in an effort to estimate pecan yield as a function of pest population or pest control variables and other productive inputs and environmental conditions. Only one equation was estimated for which over 30 percent of yield variation was explained. That equation is presented below.

$$Y_u = 55.97 + 3.08\ W + 0.90\ Y_{ut-1},\ - 5.11\ R - 101.56\ D$$

$$(R^2 = 0.38)$$

Where: Y_u = yield for Stuart variety in pounds per tree

W = diameter of tree trunk in inches

Y_{ut-1} = yield (pounds per tree) in the previous year

R = inches of rainfall between August 15 and October 1

D = pounds of dialifor applied

Only one pest control variable was significant and it was believed that its significance was merely spurious. In the equation above, 62 percent of the variation in Stuart variety pecan yield remains unexplained.

The attempt to estimate a significant pecan production function from available data was unsuccessful. The sample size was small and variation in the factors affecting yield was insufficient for a meaningful regression analysis.

Appendix II: A Note on Experimental Design

An objective of the evaluation of a multi-pest management program for pecans was to determine whether or not and to what extent the pest control method used affects pecan yield. Analysis of variance results showed that there was a significant difference between mean yield obtained on a pest management pecan plot and that on a conventionally treated plot in 1977. The existence of significant difference is a necessary but not a sufficient condition to establish a causal relationship between two variables. To establish a causal relationship it is necessary to conduct an experiment in which an independent variable is manipulated by the experimenter, and the effects of the manipulations are reflected in the dependent variable. All untested independent variables must either be held constant or randomized so that their variation does not interfere with the test of the variable of interest.

The primary problem with the design of the experiment conducted in Byron, Georgia 1975-1977 was that it utilized only two experimental plots. The only manipulated variation between plots was the difference in pest control practice. Site related factors could have varied between plots but those factors were neither consciously manipulated nor randomized. Hence, it was not possible to test for causation.

A different approach could be taken to improve the design of the experiment to test the yield effect of utilizing the pecan pest management program. Site related factors of pecan yield variation could be randomized

by spreading experimental acreage over a number of randomly selected, non contiguous plots. The assumption behind this type of experimental design is that by pooling randomly selected samples, the mean values of normally distributed site related variables will be obtained; only consciously manipulated independent variables should cause variation in the mean of the dependent variable. Both the pest management and check plot acreages would have to be randomly distributed among a number of plots. In that way, the mean and distribution of untested variables can be assumed to be constant between treatments and only the difference in pest control would affect pecan yield.

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